Claims

[c1] We claim:

1. A reformer for converting a hydrocarbon fuel into hydrogen gas and carbon dioxide, comprising:

(a)a first vessel having a partial oxidation reaction zone and a separate steam reforming reaction zone that is distinct from said partial oxidation reaction zone, said first vessel having a first vessel inlet at the partial oxidation reaction zone and a first vessel outlet at the steam reforming zone;

(b)a helical tube extending from about the first vessel, said tube having a first end for connection to an oxygen source, and a second end connected to the first vessel inlet whereby oxygen gas from said oxygen source can be conducted through said helical tube to said first vessel; and

(c)a second vessel having a second vessel inlet and second vessel outlet, said second vessel being annularly disposed about the first vessel, whereby said helical tube is disposed between the first vessel and the second vessel and gases from the first vessel can be directed through said second vessel.

[c2] 2. The reformer of Claim 1 wherein the first vessel inlet is configured to direct the oxygen gas tangentially around the interior of the first vessel.

[c3] 3. The reformer of Claim 1 wherein said oxygen source includes air.

[c4] 4. The reformer of Claim 1 wherein the helical tube is connected to a hydrocarbon source which allows the oxygen gas and the hydrocarbon to mix within the helical tube.

[c5] 5. The reformer of Claim 4 wherein the helical tube is connected to a steam source which allows the oxygen gas and the hydrocarbon to mix within the helical tube with steam from the steam source.

[c6] 6. The reformer of Claim 1 wherein said steam reforming zone includes a first catalyst.

[c7] 7. The reformer of Claim 6 wherein said first catalyst includes a nickel catalyst.

[c8] 8. The reformer of Claim 1 wherein said first vessel includes an ignition means.

[c9] 9. The reformer of Claim 1 wherein a third vessel is annularly disposed around the second vessel and said third vessel has a third vessel inlet and third vessel outlet for directing gases from second vessel through third vessel.

[c10] 10. The reformer of Claim 9 wherein said third vessel has a high-temperature shift zone.

[c11] 11. The reformer of Claim 10 wherein said high-temperature shift zone has a second catalyst.

[c12] 12. The reformer of Claim 11 wherein said second catalyst of said high-temperature shift zone includes iron oxide.

[c13] 13. The reformer of Claim 12 wherein said third vessel has a low-temperature shift zone.

[c14] 14. The reformer of Claim 13 wherein said low-temperature shift zone has a third catalyst.

[c15] 15. The reformer of Claim 14 wherein said third catalyst of said low-temperature shift zone includes copper.

[c16] 16. A method for converting a hydrocarbon fuel into hydrogen gas and carbon dioxide, comprising the steps of:
(a)directing an oxygen gas through a helical tube, said tube being disposed around a first vessel;
(b)directing a hydrocarbon vapor and steam into the helical tube to form a mixture of an oxygen gas, hydrocarbon vapor and steam;
(c)directing the mixture of the oxygen gas, hydrocarbon vapor and steam into the first vessel, whereby said hydrocarbon vapor spontaneously partially oxidizes to form a heated reformate stream that includes carbon monoxide and hydrogen gas;

(d)steam-reforming the remaining hydrocarbon vapor in the heated reformate stream to form hydrogen gas and carbon monoxide;
(e)directing the heated reformate stream over the helical tube, whereby the heated reformate stream heats the mixture in the helical tube;
(f)converting a portion of the carbon monoxide gas of the reformate stream to carbon dioxide gas by a high-temperature shift reaction; and
(g)converting at least a portion of the remaining carbon monoxide gas of the reformate stream to carbon dioxide by a low-temperature shift reaction, thereby forming a product stream including hydrogen gas and carbon dioxide.

[c17] 17. The method of Claim 16 wherein the oxygen gas is directed tangentially around the interior of the first vessel.

[c18] 18. The method of Claim 16 wherein the oxygen gas includes air.

[c19] 19. The method of Claim 16 wherein the hydrocarbon vapor and oxygen gas are mixed prior to directing the hydrocarbon vapor and oxygen gas into the first vessel.

[c20] 20. The method of claim 19 wherein the hydrocarbon vapor and oxygen gas are further mixed with steam.

[c21] 21. The method of Claim 16 wherein the hydrocarbon vapor is steam reformed in the presence of a first catalyst.

[c22] 22. The method of Claim 21 wherein the first catalyst includes a nickel catalyst.

[c23] 23. The method of Claim 16 wherein the steam reforming is conducted in a temperature range of between about 700 and 900 E C.

[c24] 24. The method of Claim 16 wherein the high temperature shift reaction is conducted in the presence of a second catalyst.

[c25] 25. The method of Claim 24 wherein the second catalyst includes iron oxide.

[c26] 26. The method of Claim 16 wherein the high temperature shift reaction is conducted in a temperature range of between about 300 and 600 E C.

[c27] 27. The method of Claim 16 wherein the low temperature shift reaction is conducted in the presence of a third catalyst.

[c28] 28. The method of Claim 27 wherein the third catalyst includes copper.

[c29] 29. The method of Claim 16 wherein the low temperature shift reacting is conducted in a temperature range of between about 150 and 300 E C.

[c30] 30. A reformer for converting hydrocarbon fuel into hydrogen gas and carbon dioxide, comprising:
a)a first tube, wherein said first tube has a first tube inlet for receiving a first mixture of an oxygen-containing gas and a first fuel and a first tube outlet for conducting a first reaction reformate of said first mixture;
b)a second tube, annularly disposed about the first tube, wherein said second tube has a second tube inlet for receiving a second mixture of a second fuel and steam, said second tube having a second tube outlet for conducting a second reaction reformate of said second mixture; and
c)a catalyst reforming zone annularly disposed about the second tube, wherein the first reaction reformate and second reaction reformate can be conducted through the first tube outlet and second tube outlet, respectively, to the catalyst reforming zone for further reforming of said mixtures.

[c31] 31. The apparatus of Claim 30 wherein a hydrocarbon fuel fractionator is attached at said first tube inlet and second tube inlet, whereby said fractionator can separate a heavy portion from the hydrocarbon fuel for subsequent direction to said partial oxidation zone, whereby a light portion can be separated from the hydrocarbon fuel for subsequent direction to said steam reforming zone.

[c32] 32. The reformer of Claim 30 wherein said oxygen gas includes air.

[c33] 33. The reformer of Claim 30 wherein the first fuel and the second fuel are

the same.

[c34] 34. The reformer of Claim 30 wherein the first fuel includes distillate fuels, gasoline and alcohols.

[c35] 35. The reformer of Claim 30 wherein the second fuel includes distillate fuels, gasoline and alcohols.

[c36] 36. The reformer of Claim 30 wherein a catalyst of catalyst reforming zone is selected from a group consisting of nickel, palladium, platinum, rhodium and ruthenium.

[c37] 37. A method for converting hydrocarbon fuel into hydrogen gas and carbon dioxide, comprising the steps of:
a)conducting a first mixture of an oxygen-containing gas and a first hydrocarbon fuel into a first tube, whereby the first hydrocarbon fuel of said first mixture spontaneously partially oxidizes to form a first heated reformate stream that includes hydrogen gas and carbon monoxide;
b)conducting a second mixture of a second hydrocarbon fuel and steam into a second tube annularly disposed about said first tube, whereby said second hydrocarbon fuel of said second mixture partially steam reforms to form a second heated reformate stream that includes hydrogen gas and carbon monoxide; and
c)directing said first heated reformate stream and second heated reformate stream through a catalyst reforming zone to further reform said reformate streams.

[c38] 38. The method of Claim 37 wherein the hydrocarbon fuel, prior to direction into the first tube and second tube, is fractionated into a heavy portion of the hydrocarbon fuel, said portion subsequently being directed to said partial oxidation zone, and into a light portion of the hydrocarbon fuel, which is directed to said steam reforming zone.

[c39] 39. The method of Claim 37 wherein air is the oxygen gas.

[c40] 40. The method of Claim 37 wherein the first hydrocarbon fuel of the first mixture and the second hydrocarbon fuel of the second mixture are the same.

[c41] 41. The method of Claim 37 wherein the catalyst reforming zone includes a first catalyst.

[c42] 42. The method of Claim 41 wherein the first catalyst is selected from the group comprising of nickel, palladium, platinum, rhodium and ruthenium.

[c43] 43. The method of Claim 37 wherein the first hydrocarbon fuel of the first mixture is selected from the group consisting of distillate fuel, gasoline, methanol, ethanol, alcohols and ethers.

[c44] 44. The method of Claim 37 wherein the second hydrocarbon fuel of the second mixture is selected from the group consisting of distillate fuel, gasoline, methanol, ethanol, alcohols and ethers.

[c45] 45. A reformer for converting a hydrocarbon fuel including a first fuel and second fuel into hydrogen gas and carbon dioxide, comprising:
a)a first tube, wherein said first tube has a first tube inlet for receiving a first mixture of steam and a second fuel and a first tube outlet for conducting a first reaction reformate of said first mixture;
b)a second tube, annularly disposed about the first tube, wherein said second tube has a second tube inlet for receiving a second mixture of a first fuel and an oxygen-containing gas, said second tube having a second tube outlet for conducting a second reaction reformate of said second mixture; and
c)a catalyst reforming zone annularly disposed about the second tube, wherein the first reaction reformate and second reaction reformate can be conducted through the first tube outlet and second tube outlet, respectively, to the catalyst reforming zone for further reforming of said mixture.